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or was slain before his natural death, so that he could not be buried in his own tomb. The high mounds in the valleys served both to protect the dead from floods and as watch-towers in time of danger.

One of the remarkable aspects of floods is their influence on the formation of valleys. Nowhere is this more clearly shown than in the valley of the Mississippi below Cairo, over which the floods distribute themselves to a width exceeding forty miles in many places. This valley has a bed of alluvial silt deposited in past flood times increasing from forty feet at Omaha and Dubuque to 300 feet at and below New Orleans. In other words, the flood alluvial deposit of the Mississippi covers 80,000 square miles to an average depth of 170 feet, a surface equal to Montana. In this elastic valley the floods annually work out the destiny of the river's bed, which is often found miles from its previous course after high water.

The ice-gorges which dam up the rivers and hold back the waters for hundreds of miles are another destructive factor of floods. When they break the resulting destruction is enormous. Congress has only to supply its existing snag-boats with dynamite in order to destroy these before the damage force is accumulated. The Government signal service along the rivers can give warning of their formation.

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THE PROBLEM OF THE SOARING BIRD.

BY I. LANCASTER.

(Continued from p. 1058, November number.)

AS soaring is a phenomenon dependent entirely on bird and air, which are not connected with the earth, to avoid confusion it is best to pay no attention to the latter. For instance, a bird motionless in regard to a point on the earth facing a five-mile-per-hour breeze; the same bird moving in calm air at the rate of five miles per hour, or going with the wind at the rate of ten miles per hour, are identical in character so far as soaring is concerned. In each case the wind is meeting the bird at the rate of five miles per hour, and the differences of translation over the earth are accidental, not concerned with the mechanical activities of flight.

A bird resting in a minimum breeze cannot fall to the rear without descending; neither can it rise vertically nor at any angle obliquely to the rear. It can draw forward on the air at any speed, and when the minimum is exceeded, can then fall to the rear, or rise until the minimum is once more reached. At the minimum velocity the bird's wings are stretched to their extreme limit and the angle of inclination is the greatest. As the breeze stiffens, the bird, if it remains in the same place, flexes its pinions and reduces its incline. The frigate bird will float in a storm with not more than one-quarter of its wing surfaces exposed. Sometimes it bends the points of its wings downwards until they meet underneath.

The positions of the stretched wings in regard to a level with the body of the bird also varies. Those of the frigate bird will average level, the buzzards will be above and the gannets below a level.

For at least three hundred days in the year these birds could be observed in the air, and when the attention was given to their actions for a considerable time, at all seasons, and in the various situations found on so varied a coast as that between Tampa bay and the Capes of Florida, not only the habitual methods common to ordinary soaring flight, but the unusual ones, incidentally performed to meet some emergency, were witnessed. The birds also have periodic seasons of feeling which puts them on behavior that in a man would be thought idiotic. The months of February and March, the time of breeding, are prolific in these singular air-tumbling performances. They served to emphasize the complete difference between active and fixed wing flight.

Being informed by parties from Charlotte's harbor that sandhill cranes could be found there, I sat out in search of them. An outside passage of thirty miles was required, which was safely made, and at nightfall I was among the Gasparilla keys. The wind being favorable and the weather fair, I kept on the outer beach, and at length drifted through a pass with the swiftly running tide in company with innumerable sharks, porpoises and fish, great and small, all headed for the bay. Rounding the point I threw over the anchor, and enveloped in a blanket with face towards the stars, slept, as one who manages a small boat for twenty hours can sleep. About daylight I was awakened by the thumping of the mast against the limb of a stunted cedar tree obliquely jutting from the bank, and while adjusting the trouble a well-known cry sounded far above in the air, which at once banished all desire to sleep. I knew the note quite well. It denoted the arrival of sandhill, or whooping, cranes from the north. Twenty-five years before I had seen them on the western prairies lift themselves on fixed wings above the clouds, and I had no doubt but what the call proceeded from birds which had the evening before been in the region of the great lakes of our northern boundary. Before sunrise at least fifty had arrived, and were greeted by their comrades on the land in the interior of the key. They came down in great circles from a height of not less than three miles, on tensely stretched wings, until within 200 feet of the earth, when they suddenly began a slow flapping which continued to the ground. I had often seen them begin their migrations, but never before witnessed the ending. They would average a weight of ten pounds, with about eight square feet of wing surface. In rising they slowly beat the air until a suitable elevation is reached, when they assume a fixed position and continue their upward flight in great circles to a high altitude, when they swing off at a tangent for the south. I have never seen one of these birds move its wings after stopping them in its ascent, until they had arrived at the same level in alighting.

The buzzards were the best species for observation from the ground. Their patience was simply inexhaustible. I watched a small flock of these birds for fourteen consecutive hours while they floated in the breeze, waiting my removal from a dead porpoise stranded on the beach. Nothing could surpass the loveliness of the day nor the bland freshness of the incoming breeze. The birds would average eight feet in spread of wings, would weigh six pounds, and have about six square feet of wing surface. A memorandum book was filled with notes of the day's experience. About a score of flaps were made between twelve and three o'clock in the afternoon when the wind was quite active and filled with flaws. From four to six in the evening they were as motionless as if petrified. As the sun disappeared behind the waters of the Gulf, I ended the hardest day's work I ever made, and was not fifty feet away before every bird had its beak in the carcass. For several days after this really imprudent exertion of the attention I was abed, but on resuming the subject determined to try an experiment. Before my eyes, assisted by a very good glass, several bodies, of six pounds weight each, had remained stationary in free air about thirty feet above the water, absolutely without any visible support. They had remained in that condition many hours, facing a breeze of velocity varying from five to twenty-five miles per hour. In the rear was located my device for determining horizontality of wind, and it was level the entire day. Most people would be less surprised at a body resting in this way in calm air than in wind. They would hold each to be simply impossible, but more mysterious that both gravity and air-resistance should be ignored, than simply gravity. So to determine how much force it would take to keep six pounds in air all the time unsupported, I provided a billet of wood of that weight, well rounded, and proceeded to throw it up in still air, and the moment it came down, catch and return it. The work was honestly done; the moment it descended it was tossed back with all the activity I was capable of commanding. I prefer that each one should try this for themselves, and will only say that an hour of such work was far, very far, beyond my muscular capacity.

These birds were often watched from a perch in some lonely tree at the water line. That I could recline at ease in the fragrant foliage of the pine was easily accounted for; the trunk of the sturdy tree antagonized the gravitating force of my body, and I could rest at peace. But what held up the birds? Had gravity ceased to act upon them? Had they no resistance to offer to that sea-born breeze?

After about four years of this kind of work accident favored me. A summer whirlwind, on a calm morning, issued from among the lemon trees straggling over the point a few hundred yards below, and clutching an armful of dead leaves made for the bay obliquely in front of my station in the tree. A pair of buzzards were returning from the outer beach on fixed wings, and as luck would have it, were intercepted by the cyclone, and in five seconds were ducked in the waters of the bay. I hope they possessed a sense of humor, but they seemed to blame me for the mishap. A more thoroughly laughable episode I never witnessed, and from the bottom of my heart forgave the creatures for their seeming injustice. They abandoned that part of the coast but left their secret behind them.

For the purposes of this paper enough has now been said as to the facts exhibited. It is very evident that a state of things has been found to exist which calls for something better than guesswork in way of explanation. Taking the case of a ten-pound bird with tensely stretched and motionless wings, facing a breeze anywhere from two to one hundred miles per hour, and resting serenely over the same spot of earth, without effort and without fatigue, we find our habitual notions about the difficulty of keeping unsupported substances in the air at fault. We want a solution of the matter from the standpoint of the mechanical engineer. We need not go into the domain of molecular physics for answers, but we wish the bird explained in the same way that a steam-engine is explained when we examine it as a machine doing work. To this end we may ask three questions, and satisfactory answers being found thereto, the phenomenon will be comprehended.

1. From whence is derived the motive power to balance gravity?
2. From whence is derived the motive power to hold the bird against the wind?
3. How are these forces applied?

To explain a steam-engine in this same sense but two questions demand answer.

1. From whence comes the motive power to drive the piston?
2. How is this force applied?

When we say that the force which moves the engine comes from the coal that is burning in the furnace, and is conducted through pipes by the medium of steam to a movable piston which it sets in motion, we have, in a general way, given an explanation to the activities there going on. When we say that the grindstone is operated by the force derived from the muscular organization of the boy turning it, then its action is also explained briefly.

It is in this way that an attempt will be made to explain a soaring bird. No objection is taken to the view that force cannot produce motion, held by some recent scientists. Granted that nothing but motion can produce motion, and I am then only concerned with the sequence of events; with having it understood that the motion of the piston is not the cause of the burning coal, nor that the grindstone turns the boy.

When the trifling tornado struck the birds as above related, the mechanical activities going on between bird and air were thrown into confusion, and the gravitating force of the bird's mass instantly carried it to the water. It was evident that the internal adjustments to environing conditions, going on through a line of ancestry reaching to the reptiles of the secondary age, omitted summer cyclones. They were too rare to count. It was also pretty clear that the gravity of the bird's mass was the source of the entire motive power concerned in the act of soaring.

Were we dealing with wind-mills, sailing vessels, tornadoes or any other phenomenon in which the air was one factor and a body connected with the earth the other, the force would properly be spoken of as coming from the air. The amount of force would vary with the velocity of the wind. The work done would be referred to the mechanical agency which set the air in motion. But a body suspended in free air is part of the atmosphere, and at rest with it, unless it employs some activity not derived from it. The same mechanical agent which moves the air equally moves the body. The active birds derive the force to move themselves in the air from their muscular efforts, the soaring birds from gravity. Gravity gives *all* the motive power; that which antagonizes itself and that which antagonizes air resistance. The case is analogous to that of a man on a moving train of cars. He is at rest with the train throughout unless he employs muscular power to set up motion with it. All activity between man and car is due to the man's force and not to the train's force. His force works a pair of legs which set up motion. Gravity works in a different way. It requires a device which compresses air as found in the soaring birds.

Notice also that the mechanical action known as "soaring" takes place only between the minimum and maximum velocities with which body and air meet. An initial impulse is required in all cases to carry the body within those limits. In a calm, the body would have to be pushed on the air until the minimum was reached. In a breeze it would be forcibly held to reach the same result. The first impulse resembles pushing an engine off of the dead center. It simply starts the machine. It has nothing whatever to do with its continuous running. Once within the limits of "soaring," the gravitating force of the body gives a liberal supply of power for all the purposes of air navigation.

Let us suppose the wing surfaces to be twelve inches in width and the bird to weigh ten pounds, with wing expanse sufficient to soar in wind moving at the rate of thirty feet per second horizontally. Why does not the body fall? It is true that there is a stiff wind moving against it horizontally, but the gravitating force is vertical and can be in no way influenced by a horizontal force. The ball shot from a level cannon falls precisely as fast as one dropped from the mouth of the gun. It is evident that the body is indifferent to the horizontal air. This does not act upon it at all. No particle of air influences it but what is in contact with its surface, and the instant it is in contact it ceases to be horizontal, being deflected in numberless different directions. In a strict sense, in a sense which alone represents the true character of this phenomenon, the air can only be considered as quiescent in every case of soaring. In every case the air is a dead calm until it comes in actual contact with the body, and the movement of the body on the air is a consequence of force derived from the body and not from the air. It is a parallel case with the boy and grindstone. From the reciprocal nature of action and reaction, the air is doing as much work on the bird as the latter is on the air. The grindstone is doing as much work on the boy as he is on the grindstone, still it would never do to say that the latter turned the boy.

If gravity, then, be the motive power of a soaring bird, how does it act to produce the results? Vertically downwards towards the center of the earth precisely as it does in all other cases, and the reason that the body manifesting it does not get lower, is because something is pushing up, against the under surface, just hard enough to balance the weight. It may be hard to follow all the peculiarities of the disturbances going on under the bird, but it is certain that they serve to hold it up. They are mainly condensations of air upon which the body is falling, and are equal to ten pounds in each foot of air passing to the rear. This ten pounds of force is moving at the rate of thirty feet per second, as we assumed at the start, and it follows that an amount capable of holding up 300 pounds each second is passing the rear edge of the bird's wings and is wasted in falling to the tension of the surrounding air.

But this is not all the force of disturbance which passes to the rear. The reactions against air resistance also go there. These, like the others, consist in condensations, accelerations and deflections. According to the law of the composition and resolution of forces they bear the same relation to the vertical disturbances which the height of the incline bears to the base, or, in other words, they are to each other as the angle of inclination of the resolving planes. Supposing in this case the height to be one-fifth the base, there would be 360 pounds of force passing the rear of the bird's wing each second. Gravity puts in 300 pounds and gets itself supported in doing it. The weight is thus balanced; but we are employing an external force of sixty pounds to push the body on the air. By the law of the action of elastic fluids under pressure, when the condensed air passes the rear edge of the wing surfaces it expands in all directions, and consequently upwards and forwards on that edge. If sixty pounds of the whole 360 expanding is thus thrown forwards, it will balance air resistance, and the total power to produce the soaring phenomenon will be the weight of the bird. It only requires one-sixth of the whole force on hand to do it. If this can be utilized by wasting the other five-sixths the task is accomplished. There would be waste in eddies and side currents, so that in reality there would be less than the total force of disturbance passing to the rear. Allowance may be freely made for all wastage and sufficient will remain to perform the desired service. Experiment shows that in very critical tests the result can be attained without the rear expansion. It may be held that each molecule of air as it is struck by the plane is, to some extent, carried with it, as well as condensed, while those below are at rest. Thus a rotary motion may be supposed to take place on the entire lower surface, when the air-resistance factor would be neutralized by the excess of gravity in each molecule instead of at the rear edge.

It has been objected that this is a disguised form of "perpetual motion." Remember that there is a great difference between heaping absurdity on a thing and finding absurdity in it. It is urged that gravity can only do work by the fall of the body manifesting it, and that in this case it does not fall; that there is no sacrifice of its energy of position, and hence it cannot do work. This is true of actions in which the earth, or anything fast to or supported by it, is a part, and the gravitating body another part; and it is true in the sense that the word "fall" means getting nearer the earth. But this is not true with soaring nor with allied phenomena, and I will illustrate the matter by an example. Suppose that our hypothetical bird rests in the air in a horizontal position and that the wind moves vertically upwards against it at the rate of twenty feet per second. To get the attention on the significant features of the case, we will suppose the bird to weigh the same as the air which it displaces, thus obliterating the gravity factor. It will then have no motion with respect to the air, but will move with it. In this condition it is not a falling body, and is doing no work. It is simply a body resting motionless in air. We will now suppose ten pounds of weight to be added to it. It instantly becomes a gravitating body doing work on the air. Its motion is accelerated until a velocity is reached at which the work done on the air is equal to the force doing it, when its motion becomes uniform. Suppose this to be twenty feet per second. What have we? A case precisely analogous to that of a soaring bird, which is a falling body doing work on the air without losing its energy of position. Its "fall" is properly related, in a strictly scientific sense, to that upon which it is moving, and upon which it is doing work. In relation to the earth, or the moon, or the seven stars it may be at rest, as they are not even remotely concerned in the matter.

A soaring bird may therefore be considered a machine for disturbing air. The motive power required for driving the mechanism is its gravitating force. Its effectiveness consists in the amount of disturbance which returns to the normal condition of the surrounding atmosphere.

There are two peculiarities connected with its action, which may be considered accidental or rather incidental, which deserve attention, for they are of the first importance in all questions relating to artificial air navigation. One of them is, that the material upon which the machine does work becomes the frame which supports it, and which is not connected with the earth in any way. The other is, that while the motion of the device is in all cases in two directions on the air upon which it operates, viz., in the direction of the gravitating force and at right angles to it, in respect to the earth's surface its motion is in any direction whatever indifferently. These two unique characteristics of soaring constitute its value for artifical use. They are the results of the action of an inclined plane driven on air, and meet the requirements of atmospheric translation completely, so far as the direction of motion and supply of motive power is concerned. It effectually disposes of balloons to antagonize gravity, and of motors to drive the machine against the air. Two requirements are still needed. The device must be steered and kept in position. When it is remembered that the rear expansion drives the bird forward, any change in the extent or position of one wing which is not shared by the other would retard or accelerate the motion of the changed side relatively to the other, and serve to determine the direction of motion. A balance still needs to be preserved. The bird gives significant hints here also. The heavier it is the steadier is its motion, and a device large enough to sustain the weight of a man may be qualified by its inertia to assist in preserving its own equipoise.

The most important points of this subject have now been given. Experiments with artificially induced currents of air, requiring a steam-engine to be transported to the sands of Florida, were expensive and productive of only negative results. Much time and means were wasted in this way, and all my efforts previous to the summer cyclone above recited seemed abortive, excepting in the settlement of the facts of soaring as shown by the birds. The moment the idea that gravity was the motive power and not the air, was entertained, the whole matter became luminous. No steps subsequently taken have been in the wrong direction, and I shall return to the prosecution of the subject the moment prudence permits.

The relation of the soaring birds to artificial air-navigation fills the whole subject with a sort of pathos. A turkey-buzzard, most despised of all the birds, employs mechanical activities by using a device of such simplicity that compared to it a common grindstone is a complex machine, for the purposes of air-locomotion in the search for carrion, with conspicuous and complete success, itself being a working model of the very thing which man has worked, and sweated, and died to possess, and he has never seen it!

For a period of time coëval with his own existence on this planet this thing has been going on, and the world is full of it now, and still the mature conviction of both common sense and science is, that it is impossible.